THE EFFECTS OF LEARNING THROUGH REPLICATIONS OF A SIMPLE SERIAL TASK

John Bradford Stevens

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

THE EFFECTS OF LEARNING THROUGH REPLICATIONS OF A SIMPLE SERIAL TASK

by

John Bradford Stevens

September 1974

Thesis Advisor: Assistant Professor D. E. Neil

Approved for public release; distribution unlimited.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) The Effects of Learning Through Replications of A Simple Serial Task		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis September 1974
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) John Bradford Stevens		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE September 1974
		13. NUMBER OF PAGES 65
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Learning, Hysteresis Phenomenon, Psychological Activation Theory

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An experiment was performed to ascertain if there existed a learning process through replication in a simple serial task. Further, it was of interest to investigate the presents of a hysteresis phenomenon with decreasing demand after a channel capacity overload. This study did not support previous conclusions concerning these processes. Specifically, learning through

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601 |
(Page 1)

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

replications did not significantly enhance performance, nor was a hysteresis phenomenon evident. This research did, in some measure, support the psychological activation theory.

The Effects of Learning Through Replications of A Simple Serial Task

by

John Bradford Stevens
Lieutenant Commander, United States Navy
B.A., Miami University, 1962

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1974

ABSTRACT

An experiment was performed to ascertain if there existed a learning process through replication in a simple serial task. Further, it was of interest to investigate the presents of a hysteresis phenomenon with decreasing demand after a channel capacity overload. This study did not support previous conclusions concerning these processes. Specifically, learning through replications did not significantly enhance performance, nor was a hysteresis phenomenon evident. This research did, in some measure, support the psychological activation theory.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX

A. Push Button Board

B. Instruction Sheet

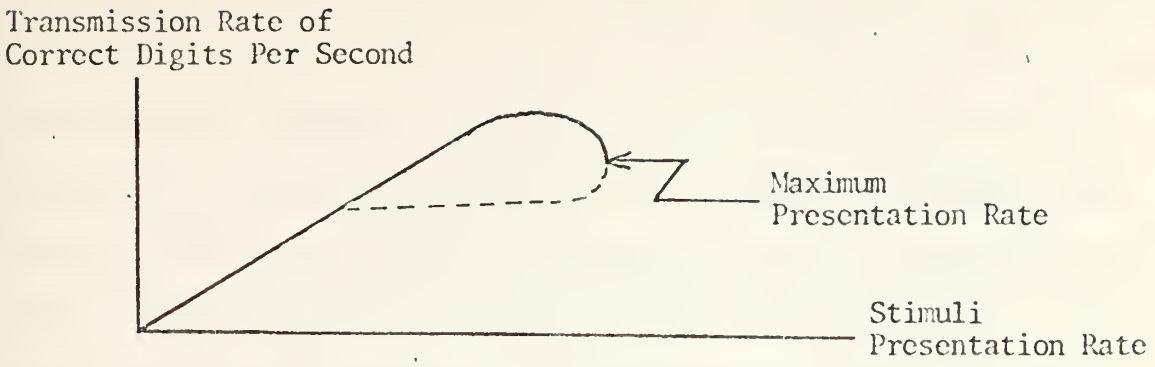
C. Graphical Representation of Statistically Significant Difference in Performance Level

D. Graphical Representation of Statistically Insignificant Difference in Performance Level

I. INTRODUCTION

Extensive research has been conducted concerning the effect of task load and stimulus presentation rate on human performance (1, 4, 5). Many experiments have examined the relationship of a subject's output in response to task demands, or increased uncertainty (1). The results of such experiments have suggested that individual subjects manifest distinct peaks of information processing and response capacity. Information loads which exceed this maximum produce a situation where a given subject cannot perform within an acceptable error rate, the acceptable error rate being determined by the criticality of the task.

Cumming and Croft (2) have suggested that the information load peak has directional dependency. That is, the location of this maximum transmission rate or performance peak may be dependent on the manner in which the stimulus is presented. They observed that a subject whose performance level had been exceeded (i.e. one which exceeded an individual's capacity) followed by a gradual reduction in stimulus presentation rate and thereby enabling acceptable level of performance, consisted of lower presentation rate than the peak attained when the task demand was initially minimal and then continually increased to the point where performance was at a maximum. In the study done by Cummings and Croft (2) the performance curves for increasing demand were superimposed over the performance curves for decreasing demand and a notable lag in the level of performance in the case of the decreasing demand was evident. This so called "hysteresis" phenomenon, or lagging behind, was tested by a nonparametric median test and was found to be statistically significant at the .01 level. (See Figure 1).



Solid line represents performance during a constantly increasing stimuli presentation rate. Dashed line represents performance during which the stimuli is being reduced to a level whereby subjects can again correctly respond to all stimuli correctly. This detrement, or lagging behind, in performance during the decreasing stimuli presentation rate is what is referred to as the "hysteresis phenomenon."

Figure 1

Other investigators (2, 3, 9) have found this same hysteresis effect in judgments of intervals on three sensory modalities (3). In an experiment on brightness, two light sources were set apart in intensity and the subject's task was to adjust a third light equidistant in intensity from the other two lights. The intensity level at which the subjects set the third light was dependent on whether or not they compared the fixed lower light intensity to the fixed higher light intensity or in reverse order. Typically, a subject would choose the mid point in intensity between two set intensity levels of two fixed light sources at a higher intensity level if he first compared the lower level light source to the higher level light source as opposed to comparing the higher level to the lower level.

In an experiment on loudness discrimination, each subject sat before a row of five keys which he pressed to produce tones at a set frequency (3). The levels produced by the two end keys were fixed, 40db apart.

The subject was required to adjust loudness level through adjustment of intermediate keys in order to divide a 40db interval into four seemingly equal steps in loudness. Subject's responses appeared dependent on whether he listened to the loudness in ascending or descending order. Similar results were found in an extensive series of unpublished experiments on judgments of the intervals between lifted weights (9). These experiments further suggested that the hysteresis effect may vary inversely with differential sensitivity (i.e. the magnitude of separation of the interval's end points).

There have been several theories offered in explanation of this observed hysteresis phenomenon with respect to stimuli presentation rate. Cummings and Croft, (2), suggested that response capacity lags behind stimuli received at high rates of presentation. This fact seemed to imply that at higher levels of demand this time lag may be substantial and suggests the possibility that information enters the operator's short-term memory more rapidly than it can be transmitted. The results being, that the storage load is gradually increased to the point where storage capacity is exceeded. Therefore, it can be postulated that at high rates of presentation, deterioration of performance is related to an overloaded short-term memory.

Another possible explanation (2) originates with the assumption that at levels of demand below overload, a subject attempts to transmit as much of the stimulus information as possible and allows himself an increasing proportion of errors as demands increases. It can be hypothesized that subjects establish strategies whereby the task becomes self-paced, as opposed to machine-paced, by merely sampling the presented stimuli and responding to the sampled portion of the stimuli alone.

Miller (6) has researched the mechanisms by which one attempts to adjust for conditions in which the rate of incoming signals are beyond his capacity. Some of these methods include allowing errors to increase, filtering out part of the information, or queuing the incoming stimulus.

The present study was intended to investigate the possibility of a learning phenomenon taking place with repetition which would lead to the hysteresis phenomenon becoming statistically insignificant. It was postulated that if the area between the increasing demand curve and the decreasing demand curve became smaller in area after several repetitions, it would indicate that the hysteresis phenomenon was, at least in part, due to a learning process. Further, it was considered of interest to confirm the findings of Cummings and Croft (2) concerning the phenomenon of the hysteresis effect on human information processing.

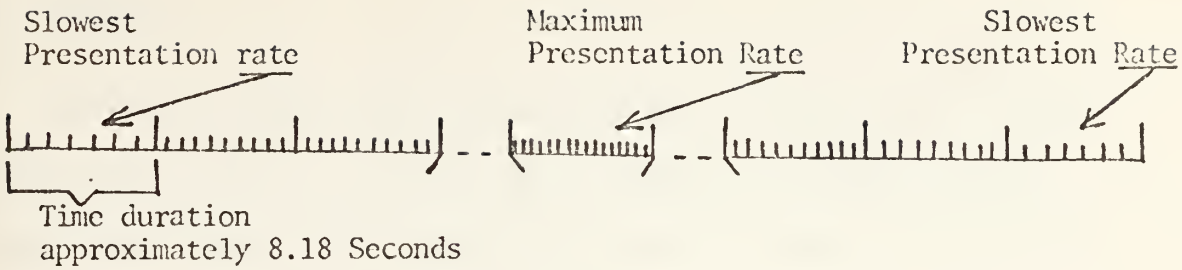
II. METHOD

A. APPARATUS

The apparatus consisted of a board with eight pushbuttons installed in a semi-circular fashion. The inner radius of this semi-circle was 4.2 inches and each pushbutton was symetrically placed 1.75 inches apart along the circumference of a semi-circle (See Appendix A). Each pushbutton had engraved on it a number, one through eight. These numbers were in sequential order from left to right. A display window, capable of displaying the integers one through eight randomly, and at controlled rates, was centrally located 5.0 inches above the pushbuttons. This entire apparatus was placed within a soundproof chamber, which aided in isolating subjects from extraneous stimuli.

The controlling apparatus was made up of a tape reader and a brush recorder. The tape reader's function was to control presentation rate of randomly coded impulses that served as stimuli. The brush recorder was used to record stimulus rate as well as to note a correct and/or incorrect response. A correct response was defined as a subject's depressing a pushbutton corresponding in number to that number appearing in the display window during the period in which the display was illuminated.

The rate at which the numbers appeared in the display window ranged from .37 digits per second to a maximum presentation rate of 1.43 digits per second. These randomized signals were started at a rate of .37 digits per second and stepped up to a maximum presentation rate of 1.43 digits per second in twelve discrete steps. The predetermined rates were .37, .45, .59, .63, .67, .71, .77, .83, .92, 1.0, 1.1, 1.25, and 1.43 digits per second. (See Figure 2).



Spikes denote time domain in which integer in display window remains lit (0.7 seconds). Presentation rate within a given 8.18 second period is obtained through adjustment of the distances between spikes.

Figure 2

Each of the rates appeared at the display window for a mean time of 8.18 seconds with .18 second standard deviation. The time duration in which the light in the display window remained on was independent of the stimulus presentation rate and was held constant at .7 of a second. Once maximum presentation rate had been reached, the rate at which the stimulus was presented was reduced to the minimum rate of .37 digit per second in twelve identical steps in reversed order. Upon completion of recording all responses of subjects during the complete cycle of increasing then decreasing stimuli presentation rate, the tape was dichotomized to separate the increasing presentation rate portion from the decreasing presentation rate portion. Subjects were then required to respond to the two sets of stimulu separately. The order in which subjects received the two independent stimuli portions, i.e. increasing rate portion of the tape or the decreasing portion, was alternated between experiment replications. During all experiment replications subjects were given a two minute rest period between each of the three tasks.

B. SUBJECTS

The subjects were eight military officers assigned to the Naval Postgraduate School. They were all enrolled in the human factors engineering option of the Operations Research program. No incentive was offered to serve as subjects.

C. PROCEDURE

Each subject read an instruction sheet that explicitly explained what his task was to be (See Appendix B). In no case were subjects made aware of the purpose of the experiment. After insuring each subject fully understood what he was to do, he was told to enter the soundproof chamber and seat himself centered in front of the display board. All subjects were instructed the manner in which they were to physically depress all pushbuttons in response to the stimuli in the display window, as well as, the precise position to take in front of the display board. All subjects were right handed with no known physical impairments. Prior to the presentation of stimuli, subjects received a three second warning that the task was about to begin. This three second warning period procedure was used for all three phases of each experiment replication. This warning period was achieved by displaying the integer "one" in the display window for a period of one second, followed by a two second period during which the display window was void. The stimulus to which the subject was to respond was then presented in the display window. In the complete cycle presentation phase, subjects were instructed to depress the appropriate pushbutton as accurately as possible whenever an integer appeared in the display window. He was

told to continue to do so, even when the task demand was beyond his capabilities, as eventually presentation rate would slow to a rate at which it was within his ability to correctly respond. The identical experiment was performed on all eight subjects for a total of ten replications over a three week period.

D. EXPERIMENT DESIGN

The Median Test and the Man-Whitney U Test were used to evaluate the data. The Median Test was considered an appropriate test, in that it determines whether two independent groups differ in central tendency. This test's power efficiency is high given that the sample size is not too large. The present study had twenty-six data points per experiment, which dictated using the Chi-square goodness-of-fit test in testing the data by means of the Median Test. The conclusions arrived at, using the Median Test, with a sample size of twenty six, (7), provided sufficient power efficiency.

To further scrutinize the data, the Man-Whitney U Test was employed. The rationale of using this test was multidimmensional in that the power efficiency is higher than the Median Test. Further, the Man-Whitney U Test does not restrict itself to comparison of the central tendencies alone. Rather, it tests whether one sample is stochastically larger than a second sample, i.e., a directional hypothesis. This non-parametric test is a most useful alternative to the parametric T Test when the researcher wishes to avoid the T Test assumptions (7). Since the sampling distribution of U rapidly approaches the normal distribution, the value of Z was calculated in order to enter the normal tables.

III. RESULTS

It was hypothesized that the hysteresis phenomenon would initially be present, but would disappear through replications of the task as a result of learning. Table I presents the results of the Median Test of performance for the non-dichotomized portion of the experiment. These results suggest that, with one exception (subject five in the fourth replication), there was no statistically significant difference. There was neither an overall increase in performance of the tenth replication, as compared to the first replication, nor was the hysteresis phenomenon reported by Cummings and Croft evidenced in this experiment.

The Chi-Square values found in Tables I through VI were obtained as follows (7).

	Increasing Task Demand	Decreasing Task Demand
Number of scores above combined Median	A	B
Number of scores below combined Median	C	D

$$\chi^2_{df=1} = \frac{N\left(\left|AD-BC\right| - \frac{N}{2}\right)^2}{(A+B)\ (C+D)\ (A+C)\ (B+D)}$$

"Score", in this case, was the number of correct responses to the varying stimuli presentation rate. The Median Test was then utilized to compare the median number of correct responses during the increasing stimuli presentation rate portion of the tape to the decreasing portion.

Table II presents the results obtained when the performance of all eight subjects was averaged on the first experiment and again on the last experiment. There was no significant difference in either case.

Table III depicts the results when the performance of each subject was averaged over the ten replications. Again there were no significant differences. (Thus in no case were there any significant differences at the level reported by Croft and Cummings (2) in the present study.)

Tables IV through VI contain results obtained using the same viewpoints as was used in Tables I through III for the dichotomized portion of the experiment. In only two cases was there significance equal to or greater than .05.

Tables VII through XII evaluate the data under the same format as was used for Tables I through VI by use of the more stringent Man-Whitney U Test. The results showed that of the 180 cases evaluated, only ten evidenced significant differences at or above .05.

The U and Z statistics found in Tables VII through XII were obtained as follows (8):

$$U = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_2$$

Where

n_1 = the number of cases in the smaller of two independent groups.

n_2 = the number of cases in the larger of two independent groups.

R_2 = sum of the ranks assigned to group whose sample size is n_2.

TABLE I

Results of the Median Test in the Analysis of Each Subject on Each of Ten Replications of the Experiment.

First Experiment

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	7 | 8 6 | 5	1	0	N.S.
2	8 | 4 5 | 9	1	1.394	N.S.
3	6 | 8 7 | 5	1	1.548	N.S.
4	8 | 6 5 | 7	1	1.1548	N.S.
5	8 | 8 5 | 5	1	0.1625	N.S.
6	7 | 5 6 | 8	1	0.1548	N.S.
7	6 | 8 7 | 5	1	0.1548	N.S.
8	6 | 7 7 | 6	1	0.0	N.S.

Second Experiment

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	6 6 7 7	1	0.1548	N.S.
2	4 6 9 7	1	0.1625	N.S.
3	6 7 7 6	1	0.0	N.S.
4	7 4 6 9	1	0.6303	N.S.
5	5 6 8 7	1	0	N.S.
6	8 5 5 8	1	0.6154	N.S.
7	8 7 5 6	1	0.0	N.S.
8	6 6 7 7	1	0.1548	N.S.

Third Experiment

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	8 6 5 7	1	0.1548	N.S.
2	7 7 6 6	1	0.1548	N.S.
3	4 5 9 8	1	0.0	N.S.
4	6 5 7 8	1	0.0	N.S.
5	6 3 7 10	1	0.6797	N.S.
6	6 6 7 7	1	0.1548	N.S.
7	7 5 6 8	1	0.1548	N.S.
8	5 5 8 8	1	0.1625	N.S.

Fourth Experiment

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	7 4 6 9	1	0.6303	N.S.
2	5 6 8 7	1	0.0	N.S.
3	5 6 8 7	1	0.0	N.S.
4	6 5 7 8	1	0.0	N.S.
5	9 3 4 10	1	3.869	.025
6	7 3 6 10	1	1.4625	N.S.
7	7 5 6 8	1	0.1548	N.S.
8	4 7 9 6	1	0.6303	N.S.

Fifth Experiment

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	6 6 7 7	1	0.1548	N.S.
2	6 5 7 8	1	0.0	N.S.
3	8 4 5 9	1	1.3929	N.S.
4	7 8 6 5	1	0.0	N.S.
5	6 6 7 7	1	0.1548	N.S.
6	6 6 7 7	1	0.1548	N.S.
7	6 6 7 7	1	0.1548	N.S.
8	6 7 7 6	1	0.0	N.S.

Sixth Experiment

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	6 4 7 9	1	0.1625	N.S.
2	6 5 7 8	1	0.0	N.S.
3	4 8 9 5	1	1.3929	N.S.
4	7 5 6 8	1	0.1548	N.S.
5	5 6 8 7	1	0.0	N.S.
6	6 6 7 7	1	0.1548	N.S.
7	8 5 5 8	1	0.6154	N.S.
8	7 6 6 7	1	0.0	N.S.

Seventh Experiment

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	7 6 6 7	1	0.0	N.S.
2	8 6 5 7	1	0.1548	N.S.
3	6 7 7 6	1	0.0	N.S.
4	7 5 6 8	1	0.1548	N.S.
5	9 6 4 7	1	0.6303	N.S.
6	6 7 7 6	1	0.0	N.S.
7	7 6 6 7	1	0.0	N.S.
8	6 6 7 7	1	0.1548	N.S.

Eighth Experiment

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	8 6 5 7	1	0.1548	N.S.
2	7 3 6 10	1	1.4625	N.S.
3	6 7 7 6	1	0.0	N.S.
4	7 6 6 7	1	0.0	N.S.
5	6 6 7 7	1	0.1548	N.S.
6	4 6 9 7	1	0.1625	N.S.
7	7 6 6 7	1	0.0	N.S.
8	7 6 6 7	1	0.0	N.S.

Ninth Experiment

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	7 6 6 7	1	0.0	N.S.
2	5 6 8 7	1	0.0	N.S.
3	6 7 7 6	1	0.0	N.S.
4	6 7 7 6	1	0.0	N.S.
5	7 3 6 10	1	1.4625	N.S.
6	6 6 7 7	1	0.1548	N.S.
7	7 5 6 8	1	0.1548	N.S.
8	5 5 8 8	1	0.1625	N.S.

Tenth Experiment

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	9 4 4 9	1	2.4615	N.S.
2	6 5 7 8	1	0.0	N.S.
3	8 5 5 8	1	0.6154	N.S.
4	4 6 9 7	1	0.1625	N.S.
5	8 6 5 7	1	0.1548	N.S.
6	5 5 8 8	1	0.1625	N.S.
7	6 7 7 6	1	0.0	N.S.
8	6 6 7 7	1	0.1548	N.S.

TABLE II

Results of The Median Test in the Analysis of the Averaged Performance of all Subjects on the First Experiment and the Averaged Performance on the Last Experiment

Experiment Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	8 | 4 5 | 9	1	1.3929	N.S.
10	6 | 6 7 | 7	1	0.1548	N.S.

TABLE III

Results of the Median Test in the Analysis of Each Subject's Averaged Performance over the Ten Replications.

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	7 | 6 6 | 7	1	0.0	N.S.
2	7 | 6 6 | 7	1	0.0	N.S.
3	5 | 6 8 | 7	1	0.0	N.S.
4	7 | 7 6 | 6	1	0.1548	N.S.
5	9 | 4 4 | 9	1	2.4615	N.S.
6	6 | 5 7 | 8	1	0.0	N.S.
7	6 | 7 7 | 6	1	0.0	N.S.
8	6 | 7 7 | 6	1	0.0	N.S.

TABLE IV

Results of the Median Test in the Analysis of Each Subject on Each of Ten Dichotomized portions of the Experiment.

First Experiment
(Increasing Rate Followed by Decreasing Rate)

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	6 | 8 7 | 5	1	0.033	N.S.
2	8 | 5 5 | 8	1	0.6154	N.S.
3	6 | 5 7 | 8	1	0.0	N.S.
4	8 | 5 5 | 8	1	0.6154	N.S.
5	6 | 5 7 | 8	1	0.0	N.S.
6	7 | 6 6 | 7	1	0.0	N.S.
7	8 | 7 5 | 6	1	0.0	N.S.
8	5 | 5 8 | 8	1	0.1625	N.S.

Second Experiment
(Decreasing Rate Followed by Increasing Rate)

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	6 7 7 6	1	0.0	N.S.
2	6 4 7 9	1	0.1625	N.S.
3	6 5 7 8	1	0.0	N.S.
4	5 7 8 6	1	.1548	N.S.
5	8 3 5 10	1	2.5212	N.S.
6	7 7 6 6	1	0.1548	N.S.
7	7 6 6 7	1	0.0	N.S.
8	8 6 5 7	1	0.1548	N.S.

Third Experiment
(Increasing Rate Followed by Decreasing Rate)

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	6 5 7 8	1	0.0	N.S.
2	6 6 7 7	1	0.1548	N.S.
3	4 3 9 10	1	0.0	N.S.
4	5 6 8 7	1	0.0	N.S.
5	7 7 6 6	1	0.1548	N.S.
6	7 7 6 6	1	0.1548	N.S.
7	7 5 6 8	1	0.1548	N.S.
8	7 6 6 7	1	0.0	N.S.

Fourth Experiment
(Decreasing Rate Followed by Increasing Rate)

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	5 6 8 7	1	0.0	N.S.
2	6 7 7 6	1	0.0	N.S.
3	5 5 8 8	1	0.1625	N.S.
4	9 6 4 7	1	0.6303	N.S.
5	8 6 5 7	1	0.1548	N.S.
6	6 6 7 7	1	0.1548	N.S.
7	7 5 6 8	1	0.1548	N.S.
8	7 5 6 8	1	0.1548	N.S.

Fifth Experiment
(Increasing Rate Followed by Decreasing Rate)

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	6 6 7 7	1	0.1548	N.S.
2	7 6 6 7	1	0.0	N.S.
3	4 7 9 6	1	0.6303	N.S.
4	5 7 8 6	1	0.1548	N.S.
5	3 7 10 6	1	1.4625	N.S.
6	7 6 6 7	1	0.0	N.S.
7	6 6 7 7	1	0.1548	N.S.
8	7 6 6 7	1	0.0	N.S.

Sixth Experiment
(Decreasing Rate Followed by Increasing Rate)

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	9 6 4 7	1	0.6303	N.S.
2	5 6 8 7	1	0.0	N.S.
3	6 7 7 6	1	0.0	N.S.
4	6 5 7 8	1	0.0	N.S.
5	6 6 7 7	1	0.1548	N.S.
6	8 6 5 7	1	0.1548	N.S.
7	9 3 4 10	1	3.869	0.25
8	6 5 7 8	1	0.0	N.S.

Seventh Experiment
(Increasing Rate Followed by Decreasing Rate)

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	5 7 8 6	1	0.1548	N.S.
2	8 6 5 7	1	0.1548	N.S.
3	6 5 7 8	1	0.0	N.S.
4	8 5 5 8	1	0.6154	N.S.
5	10 1 3 12	1	10.0848	.01
6	6 5 7 8	1	0.0	N.S.
7	8 7 5 6	1	0.0	N.S.
8	7 7 6 6	1	0.1548	N.S.

Eighth Experiment
(Decreasing Rate Followed by Increasing Rate)

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	5 7 8 6	1	0.1548	N.S.
2	5 8 8 5	1	0.6154	N.S.
3	4 9 9 4	1	1.7624	N.S.
4	6 8 7 5	1	0.033	N.S.
5	9 5 4 8	1	1.3929	N.S.
6	6 7 7 6	1	0.0	N.S.
7	6 7 7 6	1	0.0	N.S.
8	6 6 7 7	1	0.1548	N.S.

Ninth Experiment
(Increasing Rate Followed by Decreasing Rate)

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	7 4 6 9	1	0.6303	N.S.
2	7 4 6 9	1	0.6303	N.S.
3	8 6 5 7	1	0.1548	N.S.
4	7 5 6 8	1	0.1548	N.S.
5	8 6 5 7	1	0.1548	N.S.
6	7 6 6 7	1	0.0	N.S.
7	7 5 6 8	1	0.1548	N.S.
8	7 5 6 8	1	0.1548	N.S.

Tenth Experiment
(Decreasing Rate Followed by Increasing Rate)

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	3 6 10 7	1	0.6797	N.S.
2	5 5 8 8	1	0.1625	N.S.
3	4 7 10 6	1	0.6303	N.S.
4	6 7 7 6	1	0.0	N.S.
5	7 6 6 7	1	0.0	N.S.
6	7 4 6 9	1	0.6303	N.S.
7	7 7 6 6	1	0.1548	N.S.
8	5 7 8 6	1	0.1548	N.S.

TABLE V

Results of the Median Test in the Analysis of the Averaged Performance of all Subjects on the First Experiment and the Averaged Performance on the Last Experiment.

Experiment Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	7 | 5 6 | 8	1	0.1548	N.S.
10	5 | 5 8 | 8	1	0.1625	N.S.

TABLE VI

Results of the Median Test in the Analysis of Each Subject's Averaged Performance during the Ten Experiments.

Subject Number	2 X 2 Matrix Results	Degrees of Freedom	χ^2 Value	Level of Significance
1	5 | 7 8 | 6	1	0.1548	N.S.
2	6 | 5 7 | 8	1	0.0	N.S.
3	6 | 5 7 | 8	1	0.0	N.S.
4	7 | 5 6 | 8	1	0.1548	N.S.
5	8 | 5 5 | 8	1	0.6154	N.S.
6	7 | 6 6 | 7	1	0.0	N.S.
7	7 | 6 6 | 7	1	0.0	N.S.
8	6 | 6 7 | 7	1	0.1548	N.S.

TABLE VII

Results of the Mann-Whitney U Test in the Analysis of Each Subject on each of Ten Replications of the Experiment.

Experiment Number	Subject Number	U Value	Z Value	Level of Significance
1	1	80.5	-0.2052	N.S.
1	2	78.5	-0.3077	N.S.
1	3	98.5	0.7179	N.S.
1	4	70.0	-0.7436	N.S.
1	5	66.0	-0.9487	N.S.
1	6	74.5	-0.5128	N.S.
1	7	82.0	-0.1436	N.S.
1	8	91.5	0.359	N.S.
2	1	76.5	-0.4103	N.S.
2	2	92.5	0.4103	N.S.
2	3	88.5	0.2051	N.S.
2	4	53.5	-1.6316	N.S.
2	5	85.0	0.0256	N.S.
2	6	72.5	-0.6154	N.S.
2	7	63.0	-1.1026	N.S.
2	8	94.5	0.5128	N.S.

Experiment Number	Subject Number	U Value	Z Value	Level of Significance
3	1	70.0	-0.7436	N.S.
3	2	88.0	0.1795	N.S.
3	3	83.5	-0.0513	N.S.
3	4	68.5	-0.8205	N.S.
3	5	36.0	-2.4872	.01
3	6	72.0	-0.641	N.S.
3	7	79.5	-0.2564	N.S.
3	8	93.5	0.4615	N.S.
4	1	70.0	-0.7436	N.S.
4	2	95.0	0.5385	N.S.
4	3	49.5	-1.7949	.05
4	4	77.5	-0.3589	N.S.
4	5	78.5	-0.3077	N.S.
4	6	75.0	-0.4872	N.S.
4	7	88.0	0.1795	N.S.
4	8	83.5	-0.0513	N.S.
5	1	57.5	-0.1385	N.S.
5	2	76.0	-0.4359	N.S.
5	3	112.0	1.4103	N.S.
5	4	59.0	-1.3077	N.S.
5	5	85.0	0.0256	N.S.
5	6	83.0	-0.0769	N.S.

Experiment Number	Subject Number	U Value	Z Value	Level of Significance
5	7	76.0	-0.4359	N.S.
5	8	87.5	0.1538	N.S.
6	1	66.0	-0.9487	N.S.
6	2	47.0	-1.923	.05
6	3	86.0	.0769	N.S.
6	4	70.0	- .7436	N.S.
6	5	52.0	-1.6667	.05
6	6	87.5	0.1538	N.S.
6	7	81.0	-0.1795	N.S.
6	8	80.5	-0.2051	N.S.
7	1	66.0	-0.9487	N.S.
7	2	47.0	-1.923	.05
7	3	86.0	0.0769	N.S.
7	4	70.0	-0.7436	N.S.
7	5	52.0	-1.6667	.05
7	6	87.5	0.1538	N.S.
7	7	81.0	-0.1795	N.S.
7	8	80.5	-0.2051	N.S.

Experiment Number	Subject Number	U Value	Z Value	Level of Significance
8	1	74.0	-0.5385	N.S.
8	2	54.0	-1.5641	N.S.
8	3	92.5	0.4103	N.S.
8	4	75.5	-0.4615	N.S.
8	5	66.0	-0.9487	N.S.
8	6	99.0	0.7436	N.S.
8	7	76.0	-0.4103	N.S.
8	8	72.0	-0.6411	N.S.
9	1	82.5	-0.1026	N.S.
9	2	88.5	0.2051	N.S.
9	3	99.0	0.7736	N.S.
9	4	85.5	0.0513	N.S.
9	5	69.0	-0.7948	N.S.
9	6	88.5	0.2051	N.S.
9	7	65.5	-0.9744	N.S.
9	8	85.5	0.0513	N.S.
10	1	53.0	-1.6154	N.S.
10	2	79.0	-0.2821	N.S.
10	3	64.0	-1.0513	N.S.
10	4	90.0	0.2821	N.S.
10	5	66.0	-0.9487	N.S.
10	6	82.5	-0.1026	N.S.
10	7	96.0	0.5897	N.S.
10	8	78.5	-0.3077	N.S.

TABLE VIII

Results of the Mann-Whitney U Test in the Analysis of the Averaged Performance of all Subjects on the First Experiment and the Averaged Performance on the Last Experiment.

Experiment Number	U Value	Z Value	Level of Significance
1	75.0	-0.5026	N.S.
2	76.5	-0.4103	N.S.

TABLE IX

Results of the Mann-Whitney U Test in the Analysis of Each Subject's Averaged Performance During the Ten Experiments.

Subject Number	U Value	Z Value	Level of Significance
1	66.0	-0.9487	N.S.
2	75.0	-0.4359	N.S.
3	85.0	0.0256	N.S.
4	68.0	-0.8462	N.S.
5	54.0	-1.5641	N.S.
6	79.5	-0.2564	N.S.
7	72.0	-0.641	N.S.
8	82.5	-0.1026	N.S.

TABLE X

Results of the Mann-Whitney U Test in the Analysis of each Subject on Each of Ten Dichotomized Replications of the Experiment. Odd Numbered Experiments had the Increasing Stimuli Presentation Rate First Presented Followed by the Decreasing Stimuli Presentation Rate Portion of the Tape. Even Numbered Experiments had the Order of Presentation Rate Reversed, i.e., Decreasing Rate Followed by Increasing Rate.

Experiment Number	Subject Number	U Value	Z Value	Level of Significance
1	1	91.5	0.3333	N.S.
1	2	75.0	-0.4672	N.S.
1	3	92.5	0.4103	N.S.
1	4	55.5	-1.4871	N.S.
1	5	82.5	-0.1026	N.S.
1	6	90.5	0.3072	N.S.
1	7	84.5	0.0	N.S.
1	8	86.0	0.0769	N.S.
2	1	83.5	-0.0513	N.S.
2	2	67.5	-0.8718	N.S.
2	3	88.0	0.1795	N.S.
2	4	103.0	0.9737	N.S.
2	5	30.5	-2.842	.01
2	6	87.0	0.1282	N.S.
2	7	68.0	-0.8462	N.S.
2	8	76.5	-0.4103	N.S.

Experiment Number	Subject Number	U Value	Z Value	Level of Significance
3	1	82.5	-0.1026	N.S.
3	2	82.5	-0.1026	N.S.
3	3	70.0	-0.7436	N.S.
3	4	100.5	0.8205	N.S.
3	5	83.0	-0.0769	N.S.
3	6	90.0	0.2821	N.S.
3	7	92.0	0.3846	N.S.
3	8	85.5	-0.0513	N.S.
4	1	97.5	0.6667	N.S.
4	2	102.5	0.9231	N.S.
4	3	68.0	-0.8463	N.S.
4	4	42.0	-2.1795	.025
4	5	56.0	-1.4615	N.S.
4	6	83.5	-0.0513	N.S.
4	7	71.0	-0.6923	N.S.
4	8	63.0	-1.1026	N.S.
5	1	82.0	-0.1282	N.S.
5	2	79.5	-0.2564	N.S.
5	3	99.5	0.7692	N.S.
5	4	87.0	0.1282	N.S.
5	5	111.0	1.359	N.S.
5	6	87.5	0.1538	N.S.

Experiment Number	Subject Number	U Value	Z Value	Level of Significance
5	7	64.0	-1.0513	N.S.
5	8	68.5	-0.8205	N.S.
6	1	61.5	-1.1949	N.S.
6	2	96.0	0.5897	N.S.
6	3	99.0	0.7436	N.S.
6	4	72.0	-0.641	N.S.
6	5	73.0	-0.5897	N.S.
6	6	72.0	-0.641	N.S.
6	7	36.5	-2.4615	.01
6	8	73.5	-0.5641	N.S.
7	1	98.0	0.6923	N.S.
7	2	66.0	-0.9487	N.S.
7	3	71.5	-0.6607	N.S.
7	4	53.0	-1.6154	.05
7	5	26.5	-2.9744	.01
7	6	93.0	0.4359	N.S.
7	7	67.0	-0.8974	N.S.
7	8	82.5	-0.1026	N.S.
8	1	98.0	0.6769	N.S.
8	2	87.0	0.1282	N.S.
8	3	95.5	0.5641	N.S.

Experiment Number	Subject Number	U Value	Z Value	Level of Significance
8	4	108.0	1.205	N.S.
8	5	47.5	-1.8974	.05
8	6	89.5	0.2564	N.S.
8	7	100.5	0.8205	N.S.
8	8	90.0	0.2821	N.S.
9	1	77.5	-0.359	N.S.
9	2	66.5	-0.9231	N.S.
9	3	68.0	-0.8462	N.S.
9	4	81.5	-0.1538	N.S.
9	5	77.5	-0.359	N.S.
9	6	72.5	-0.6154	N.S.
9	7	62.0	-1.1538	N.S.
9	8	64.0	-0.8205	N.S.
10	1	109.0	1.256	N.S.
10	2	84.0	-0.0256	N.S.
10	3	85.0	0.0256	N.S.
10	4	90.0	0.282	N.S.
10	5	71.5	-0.6667	N.S.
10	6	80.0	-0.2308	N.S.
10	7	73.5	-0.5641	N.S.
10	8	87.5	0.1538	N.S.

TABLE XI

Results of the Mann-Whitney U Test in the Analysis of the Averaged Performance of all Subjects on the First Experiment and the Averaged Performance on the Last Experiment.

Experiment Number	U Value	Z Value	Level of Significance
1	70.5	-0.718	N.S.
2	83.0	-0.0769	N.S.

TABLE XII

Results of the Mann-Whitney U Test in the Analysis of Each Subjects Averaged Performance During the Ten Experiments.

Subject Number	U Value	Z Value	Level of Significance
1	88.0	0.1795	N.S.
2	79.0	-0.2821	N.S.
3	90.0	0.2821	N.S.
4	75.0	-0.4359	N.S.
5	53.5	-1.5897	N.S.
6	85.0	0.0256	N.S.
7	63.0	-1.1026	N.S.
8	80.5	-0.2051	N.S.

IV. DISCUSSION AND CONCLUSIONS

The results of this study did not support the findings of Cummings and Croft (2). Their observation of the presence of a hysteresis phenomenon when the transmission rate of decreasing stimuli presentation rate was compared to the transmission rate of increasing stimuli presentation rate, was not observed in the present study. Considerable variability in performance between subjects was observed in the current investigation as well as within subjects, but in no case was a recognizable pattern established. The data from the few individual replications that indicated a significant difference was plotted, in order to compare the performance levels of the increasing stimuli rate to that of the decreasing rate. A typical graph is enclosed in Appendix C. In all cases, whether a subject's higher transmission rate was during the increasing stimuli presentation phase or during the decreasing phase, performance appeared to be a random process. This randomization of performance level also prevailed in four randomly chosen individual replications where there was no statistically significant difference noted between the two phases. A graph of a typical plot is enclosed in the Appendix D.

The hypothesis that a subject's level of performance on a simple serial task would increase with replications and that this increase in performance could be attributed to a learning process was also rejected. Although in many cases subjects appeared to be increasing their level of performance as they repeated the experiment, this higher performance level being attributable to learning was not supported by statistical analysis. It was further noted that subjects who had been used in a

similar experiment involving the same apparatus as the present study did not, as a group, out perform those subjects who had no previous experience. This would seem to support the idea that the repetition of a simple serial task would not increase performance level substantially.

The present study did seem to support the psychological activation theory, i.e., "People perform best at some optimum level of activation or difficulty". (8). Intuitively it was believed that the percentage of received stimuli transmitted would be highest for the lowest stimuli presentation rate and lowest for the highest presentation rate. This postulate was not borne out in this experiment. Rather, subjects uniformly performed best at an intermediate rate. One possible explanation of this occurance is a change of tactics on the part of the subjects in performing the task. Upon completion of the experiment, all subjects were interviewed and it was found that, catagorically, subjects looked at the appropriate button prior to depressing it. As the stimuli presentation rate increased, subjects would no longer look at the appropriate pushbutton, but rather would depress a button in the general vicinity of the one desired. This appeared to improve performance at higher presentation rates up to a given rate after which performance dropped off. The point at which the subjects changed tactics in the performance of the task and their optimum level of performance varied among subjects.

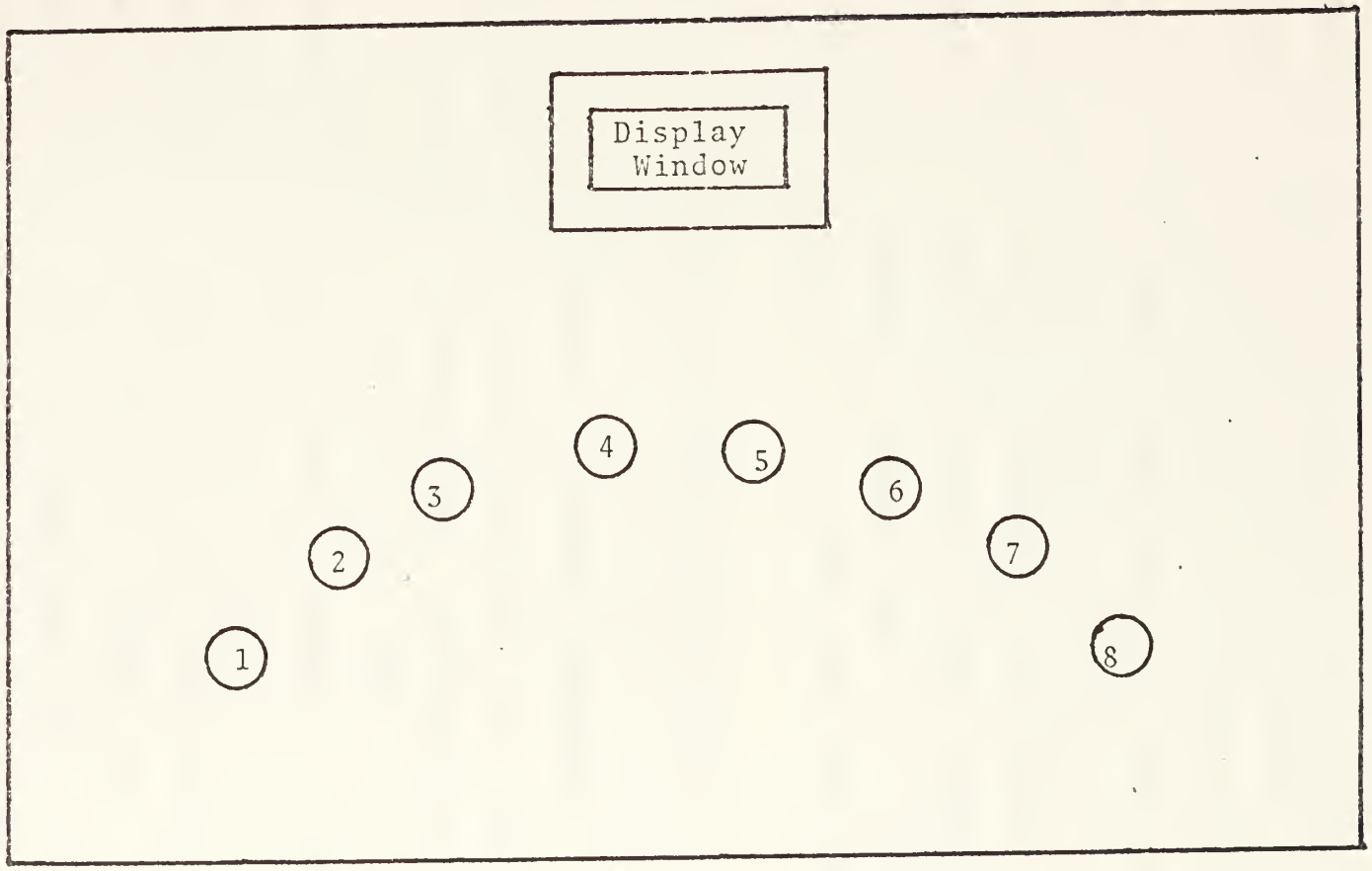
It was also noted that similar results were obtained in both the non-dichotomized portion of the experiment and the dichotomized portion. Further, there were no observable differences in performance of the dichotomized portion of the experiment relevant to the order of presentation rates, i.e., whether the increasing rate was presented

followed by the decreasing portion of the tape or in reversed order. This result was anticipated when no significant differences were found in the performance level of the non-dichotomized tape.

V. SUMMARY

In summary, the two major objectives of this study, i.e., ascertaining the presence of a learning process in a simple serial task and associating hysteresis phenomenon with decreasing demand after a channel capacity overload, were not supported. In the few isolated cases where there existed a significant difference in transmission rate when comparing the increasing stimuli presentation rate to the decreasing rate, the hysteresis phenomenon was not evident. Rather a random pattern appeared when the plotted data of the transmission rate during the increasing stimuli rate was superimposed over that of the decreasing rate. Similar results were obtained with the complete cycle and the dichotomized cycle.

The study did support the psychological activation theory. This phenomenon was observable in each of the subjects on all of the replications of the experiment. It was postulated that a change of tactics on the part of the subjects in performing the task largely accounted for this observation.



PUSH BUTTON BOARD

APPENDIX A

APPENDIX B

INSTRUCTIONS

You are to enter the sound proof chamber and sit in the chair provided that is centrally located in front of the apparatus. You will note there exists a board containing eight pushbuttons arranged in a semi-circular fashion with the integers one through eight engraved on each. The numbering will be in sequential order from left to right. Directly above the semi-circular information of pushbuttons is a display window that will randomly-light up with an integer consisting of numerals one through eight. Whenever an integer appears it will always remain lit a constant time interval of .7 seconds; however the integer presentation rate will vary.

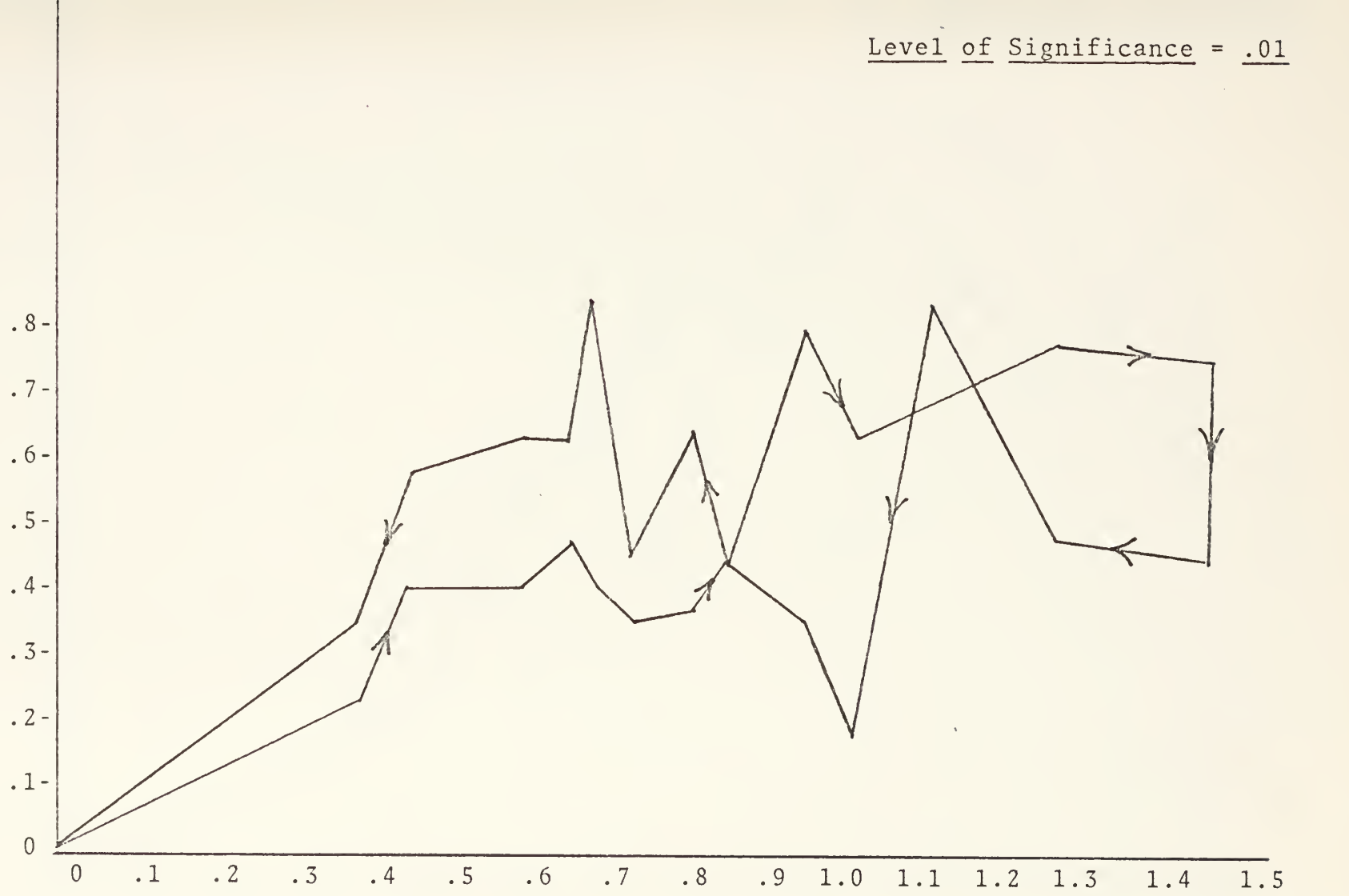
During the following prearranged days, the experiment will consist of two parts. On all occasions, you will first be presented with a cycle in which the presentation rate steadily increases in thirteen discrete steps, and then immediately decreases in the same number of steps to the original presentation rate. On alternative days the same tape will be presented in dichotomized form. That is, on odd numbered experiments after the full cycle has been presented, the increasing portion of the cycle will be presented followed by the decreasing portion. On even numbered experiments the decreasing portion will be presented followed by the increasing portion of the complete cycle. On all occasions, you will be given a two minute rest period after the full cycle and between the two dichotomized portion of the cycle.

Your task will consist of depressing the pushbutton whose integer is being displayed in the display window during the time duration a

given integer is displayed. You are asked to use only your index and middle fingers of your right hand. Should you be unable to perform at the rate the stimuli is presented, you are asked to continue to do your best and correctly respond to as many stimuli as possible. Each of the three portions of the experiment will begin with a warning consisting of the integer "one" being displayed for a period of one second followed by a two second void time. At the end of this three second warning, integers will commence being displayed to which you will respond as explained above.

Are there any questions?

Level of Significance = .01



APPENDIX C


Not Statistically Significant
1.1-
1.0-
.9-
.8-
.7-
.6-
.5-
.4-
.3-
.2-
.1-
.1-
0
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.45
Stimuli Presentation Rate
in Digits Per Second

APPENDIX D

BIBLIOGRAPHY

Cummings, R. W., "The Analysis of Skills in Driving," Journal of the Australian Road Research Board V.1, No. 9, P. 4-14, 1963.

Cummings, R. W., and Croft P.G. "Human Information Processing Under Varying Task Demands," Ergonomics V.16, No. 5, P 581-586, September 1973.

Garner, W. R., "A Technique and a Scale for Loudness Measurement," Journal of Acoustic Society of America V. 26 P. 73-88, 1954.

Knowles, W.B., Burger, W.J., Mitchell, M.B., Hanifan, D.T., and Wulfeck, J.W., "Models, Measures, and Judgments in System Design," Human Factors VII, No. 6, P. 577-590, 1969.

Knowles, W.B., Garvey, W.D., and Newlin, E.P., "The Effect of Speed and Load on Display-control Relationships," Journal of Experimental Psychology V.46, No. 2, P. 65-75, August, 1953.

Miller, J.G., "Adjusting to Overloads of Information," Disorders of Communications V.42, P. 87-100, 1964.

Siegel, S., Nonparametric Statistics, McGraw-Hill, 1956.

Snook, S.H., and Iruine, C.H., "Psychophysical Studies of Physiological Fatigue Criteria," Human Factors V. 11, No. 3, P. 291-300, 1969.

Stevens, S.S., "On the Psychophysical Law," The Psychological Review V. 64, No. 3, May, 1957.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0212 Naval Postgraduate School Monterey, California 93940	2
3.	Department of Operations Research and Administrative Sciences Naval Postgraduate School Monterey, California 93940	1
4.	Man-Machine Systems (Design) Laboratory Naval Postgraduate School ATTN: Code 55Aa Monterey, California 93940	1
5.	Asst Professor D. E. Neil, Code 55Ni Department of Operations Research and Administrative Sciences Naval Postgraduate School Monterey, California 93940	1
6.	Assoc Professor G. K. Poock, Code 55Pk Department of Operations Research and Administrative Sciences Naval Postgraduate School Monterey, California 93940	1
7.	LCDR John B. Stevens, USN 516 Northeast 21st Avenue Ocala, Florida 32670	1

153866
Thesis
S7127 Stevens
c.1 The effects of learning through replications of a simple serial task.